Section 4

Wireless Communication

Objectives

After this lesson, students will be able to

O.3.4.1 Explain how radio waves transmit information.

O.3.4.2 Describe how cellular phones work.

O.3.4.3 Explain how communications satellites relay information.

Target Reading Skill

Identifying Main Ideas Explain that using prior knowledge helps students connect what they already know to what they are about to read.

Answers

Possible answers:

What You Know

1. Cellular phones don't use wires.
2. Radio and television signals travel through the air.

What You Learned

1. The signals for radio and television programs are carried by radio waves.
2. The signals can be transmitted by changing either the amplitude or the frequency of the radio waves.
3. Cellular phones transmit and receive signals using microwaves.

All in One Teaching Resources

- Transparency O36

Preteach

Build Background Knowledge

L2

Live Satellite Broadcasts

Encourage students to recall live television broadcasts they have seen in which the signal originated on the other side of Earth, for example, in Australia. Ask: **How did the signal travel to the United States from there?** *(Sample answer: It was transmitted by a satellite.)* Tell students that in this section they will learn how these and other messages are transmitted using radio waves.

Section 4

• Tech & Design •

Wireless Communication

Reading Preview

Key Concepts

- How do radio waves transmit information?
- How do cellular phones work?
- How do communications satellites relay information?

Key Terms

- amplitude modulation
- frequency modulation

Target Reading Skill

Using Prior Knowledge Your prior knowledge is what you know before you read about a topic. Before you read, write what you know about wireless communication in a graphic organizer. As you read, continue to write in what you learn.

Lab zone Discover Activity

How Can Radio Waves Change?

1. Trace the wave diagram onto a piece of tracing paper. Then transfer the tracing onto a flat piece of latex from a balloon or a glove.
2. Stretch the latex horizontally. How is the stretched wave different from the wave on the tracing paper?
3. Now stretch the latex vertically. How is this wave different from the wave on the tracing paper? How is it different from the wave in Step 2?

Think It Over

Making Models Which stretch changes the wave's amplitude? The wave's frequency?

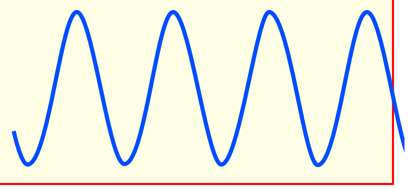


FIGURE 13
Miniature Television
Radio waves transmit the signals for this small portable television.

You race home from school and switch on the TV to catch the final innings of your favorite team's big game. In an instant, you see and hear the game just as if you were sitting in the stands.

Today you can communicate with people far away in just seconds. You can watch a live television broadcast of a soccer game from Europe or listen to a radio report from Africa. How do these radio and television programs reach you?

Radio and Television

Radio waves carry, or transmit, signals for both radio and television programs. The radio waves are produced by charged particles moving back and forth inside transmission antennas. **Transmission antennas send out, or broadcast, radio waves in all directions. Radio waves carry information from the antenna of a broadcasting station to the receiving antenna of your radio or television.** There are two methods of transmitting the signals—amplitude modulation and frequency modulation. Radio stations broadcast using either method. Television stations use both methods—amplitude modulation for pictures and frequency modulation for sound.

Lab zone Discover Activity

L1

Skills Focus Making models

Materials tracing paper, flat piece of stretchable latex about 20 cm square

Time 10 minutes

Tips Review the wave concepts of *amplitude, wavelength,* and *frequency.*

Expected Outcome The wave on the stretched latex in Step 2 is wider and spread farther apart. The wave on the stretched latex in Step 3 is taller and narrower.

Think It Over The vertical stretch (Step 3) changes the wave's amplitude. The horizontal stretch (Step 2) changes the wave's frequency.

Amplitude Modulation AM stands for amplitude modulation. **Amplitude modulation** is a method of transmitting signals by changing the amplitude of a wave. The information that will become sound, such as speech and music, is coded in changes, or modulations, of a wave's amplitude. The frequency of the wave remains constant, as shown in Figure 14. At a radio broadcasting station, sound is converted into electronic signals. The electronic signals are then converted into a pattern of changes in the amplitude of a radio wave. Your radio receives the wave and converts it back into sound.

AM radio waves have relatively long wavelengths and are easily reflected by Earth's ionosphere. The ionosphere is a region of charged particles high in the atmosphere. The reflected waves bounce back to Earth's surface. Therefore, AM radio stations can broadcast over long distances.

Frequency Modulation FM stands for frequency modulation. **Frequency modulation** is a method of transmitting signals by changing the frequency of a wave. FM signals travel as changes, or modulations, in the frequency of the wave. The amplitude of the wave remains constant.

FM waves have higher frequencies and more energy than AM waves. As shown in Figure 14, they pass through the ionosphere instead of being reflected back to Earth. Thus, FM waves do not travel as far as AM waves. So, if you go on a long car trip with an FM radio station tuned in, you may quickly lose reception of the station. But FM waves are usually received clearly and produce better sound quality than AM waves.

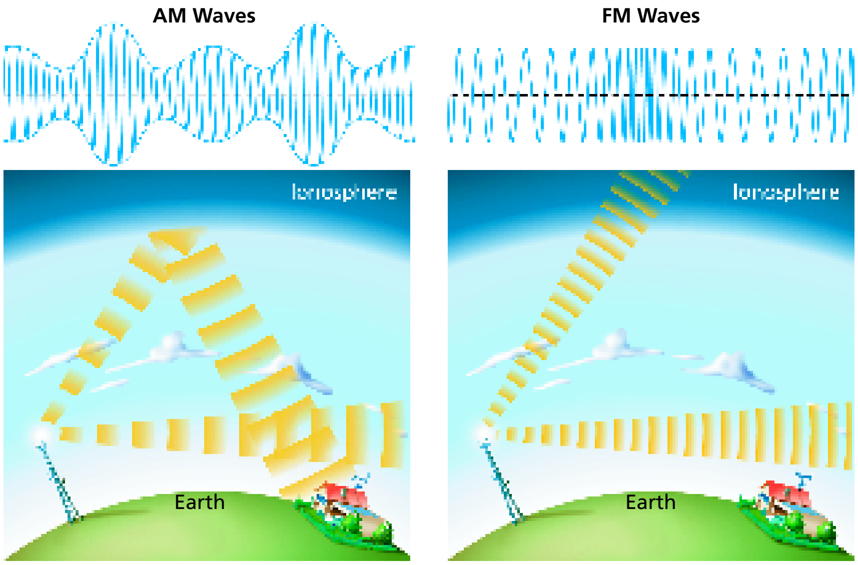


FIGURE 14
AM and FM Radio Waves
In AM transmissions, the amplitude of a radio wave is changed. In FM transmissions, the frequency is changed.
Interpreting Diagrams *What property is constant in the AM wave? In the FM wave?*

Instruct

Radio and Television

Teach Key Concepts L2

Introducing AM and FM Radio Waves

Focus Tell students that there are two ways of sending signals with radio waves: amplitude modulation and frequency modulation.

Teach State that modulation means "change." Ask: **What do you think amplitude modulation means?** *(Change in amplitude)* **What do you think frequency modulation means?** *(Change in frequency)* Have students look at Figure 13 and read the caption. Point out how amplitude changes in the AM wave and how wavelength changes in the FM wave.

Apply Ask: **If the wavelength of FM waves changes, what happens to their frequency?** *(It also changes, but in the opposite direction.)* **Why?** *(Because the product of wavelength and frequency is the speed of light, which is constant for electromagnetic waves in a given medium)* **learning modality: logical/mathematical**

All in One Teaching Resources
- Transparency O37

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *Wireless Communication*

Student Edition on Audio CD

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Ask Questions
Distribute a rewritten, simplified version of the paragraph under the *Radio and Television* heading. Ask straightforward questions that can be answered directly from the rewritten text. For example, ask: **What are two methods of transmitting signals in radio and television broadcasts?** **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Ask Questions Have students read the simplified paragraph and the actual text paragraph. Ask if they find anything confusing in the text paragraph, and try to clarify it for them. Finally, check comprehension by asking questions based on the actual text. For example, ask: **What happens to radio waves that reach your radio or television?** **learning modality: verbal**

Monitor Progress L2

Skills Check Have students create a Venn diagram comparing and contrasting AM and FM radio waves. Students can keep their Venn diagrams in their portfolios.

Portfolio

Answer
Figure 13 In the AM wave, frequency is constant. In the FM wave, amplitude is constant.

Math Analyzing Data

Math Skill Interpreting data

Focus State that different types of radio and television broadcasts are restricted to using radio waves of a certain range of frequencies.

Teach Point out the units used to measure wave frequency. Make sure students know that kHz represents kilohertz, or 1,000 hertz, and that MHz represents megahertz, or 1,000,000 hertz. Ask: **Which frequency is greater, 54MHz or 1,605 kHz?** *(54 MHz)*

Answers

1. Kilohertz (kHz) and megahertz (MHz)
2. UHF television uses the highest-frequency radio waves, and AM radio broadcast uses the lowest-frequency radio waves.
3. UHF television uses waves with the highest frequency and therefore the shortest wavelength.
4. You cannot tell from this data if it is a television or radio program, because VHF television and FM radio both broadcast radio waves with a frequency of 100 MHz.

Help Students Read L1

Visualizing Refer to the Content Refresher in this chapter, which provides guidelines for using the Visualizing strategy.

Suggest that students visualize the radio spectrum as a band of increasing wave frequencies, like the electromagnetic spectrum band diagrammed in Figure 3 of Section 2, *Waves of the Electromagnetic Spectrum*. Help students visualize the order of waves in such a radio band diagram by asking: **Which type of radio waves would you place at the low-frequency/long-wavelength end of the diagram?** *(AM radio waves)*. **Which type of radio waves would you place at the high-frequency/short-wavelength end of the diagram?** *(UHF television)* **Which type of radio waves would follow AM radio in the diagram?** *(VHF television)* You might want to have students actually draw and label such a radio band diagram to help in their visualizing.

Math Analyzing Data

Comparing Frequencies

The table shows the ranges of radio broadcast frequencies used for AM radio, UHF television, FM radio, and VHF television.

1. **Interpreting Data** In the table, what units of measurement are used for frequency?
2. **Interpreting Data** Which type of broadcast shown in the table uses the highest-frequency radio waves? Which uses the lowest-frequency waves?
3. **Calculating** Which type of broadcast uses waves with the shortest wavelength?

Broadcast Frequencies

Type of Broadcast	Frequency Range
AM radio broadcast	535 kHz to 1,605 kHz
VHF television	54 MHz to 216 MHz
FM radio broadcast	88 MHz to 108 MHz
UHF television	470 MHz to 806 MHz

4. **Inferring** A broadcast uses a frequency of 100 MHz. Can you tell from this data if it is a television or a radio program? Explain.

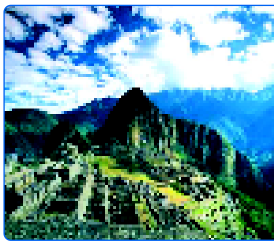
Discovery Channel School
The Electromagnetic Spectrum
Video Preview
▶ Video Field Trip
Video Assessment

The Radio Spectrum In addition to radio and television broadcasts, radio waves are used for many types of communication. For example, taxi drivers, firefighters, and police officers all use radio waves to do their jobs. The Federal Communications Commission, or FCC, assigns different radio frequencies for different uses. Radio stations are allowed to use one part of the radio spectrum. Television stations use other parts. Taxi and police radios are also each assigned a set of frequencies. Because the signals all have different assigned frequencies, they travel without interfering.

You probably have seen these assigned frequencies when you tune a radio. AM radio stations use frequencies measured in kilohertz (kHz), while FM radio stations use frequencies measured in megahertz (MHz). Recall that a hertz is one cycle per second. If something vibrates 1,000 times a second, it has a frequency of 1,000 Hz, or 1 kilohertz (kHz). (The prefix *kilo-* means "one thousand.") If something vibrates 1,000,000 times a second, it has a frequency of 1,000,000 Hz, or 1 megahertz (MHz). (The prefix *mega-* means "one million.")

AM radio stations range from 535 kHz to 1,605 kHz. FM radio stations range between 88 MHz and 108 MHz. A television station uses one of two sets of frequencies: Very High Frequency (VHF) or Ultra High Frequency (UHF). VHF stations range from 54 MHz to 216 MHz, corresponding to Channels 2 through 13 on your television set. UHF channels range from 470 MHz to 806 MHz, corresponding to Channels 14 through 69.

Reading Checkpoint What does the term *kilohertz* stand for?



Discovery Channel School Video Field Trip

The Electromagnetic Spectrum

Show the Video Field Trip to let students see how electromagnetic waves are used to help find ships or people lost at sea. Discussion question: **What characteristic of radio waves makes them an important part of search-and-rescue operations?** *(Some radio waves can travel from Earth into space and back again.)*

Cellular Phones

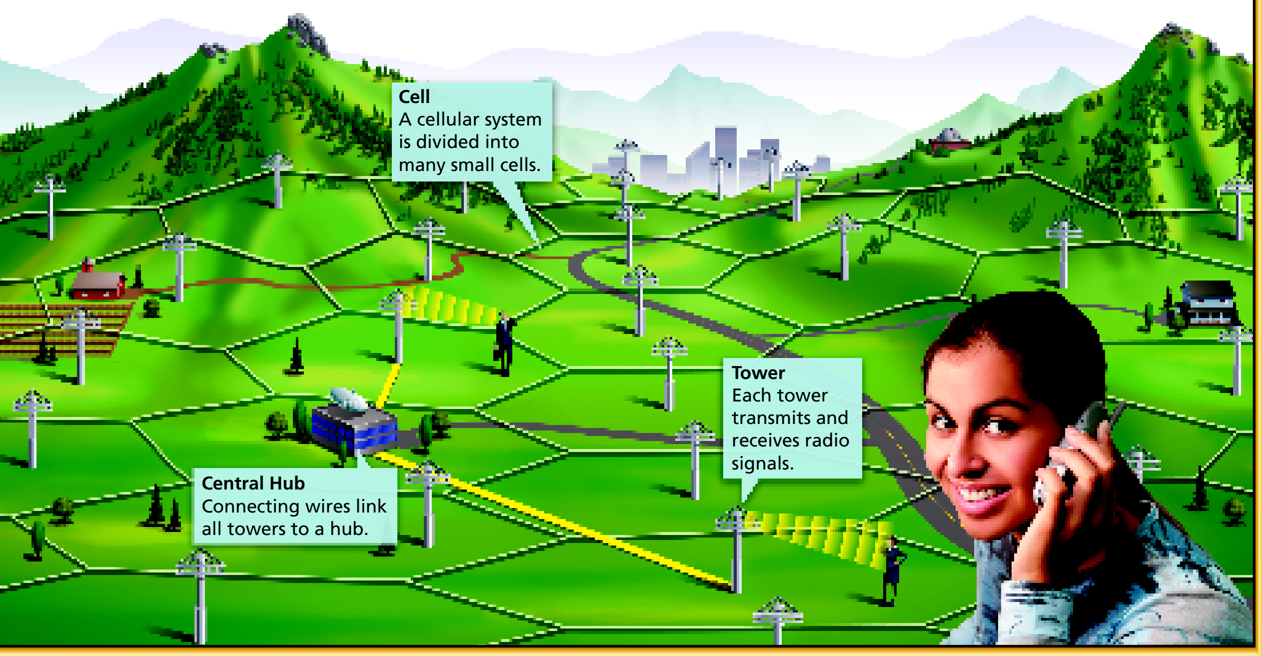
Cellular telephones have become very common, but they only work if they are in or near a cellular system. The cellular system, which is shown in Figure 15, works by dividing regions into many small cells, or geographical areas. Each cell has one or more towers that relay signals to a central hub.

Cellular phones transmit and receive signals using high-frequency microwaves. When you place a call on a cellular phone, the phone sends out microwaves. The microwaves are tagged with a number unique to your phone. A tower picks up the microwaves and transfers the signal to a hub. In turn, the hub channels and transmits the signal to a receiver. The receiver may be another tower or another hub, depending on the distance between the two phones. That tower or hub transmits the signal to the receiving cellular phone. The receiving phone rings when it picks up the microwave signal from a tower or hub. The whole exchange seems to be instantaneous.

In addition to making phone calls, you can also use some cellular phones to page someone, to send text messages, or to get information from the Internet. Some modern cellular phones can even be used as digital cameras.

Reading Checkpoint **What are three ways to communicate with a cellular phone?**

Figure 15
Cellular Phone System
In the cellular phone system, cellular phones transmit and receive radio waves that travel to the nearest tower.
Predicting *What happens if a cellular phone is far away from a tower?*



Differentiated Instruction

Less Proficient Readers (L1)

Using Prior Knowledge of Cellular Phone Towers Challenge students to locate two or more adjacent cellular phone towers in the area. Ask: **How far apart are the towers?** *(The towers are likely to be a few miles apart.)* **Why are cellular phone towers so close together?** *(Because cellular phones transmit weak signals)* **learning modality: visual**

Gifted and Talented (L3)

Cellular Phone Frequencies Challenge interested students to find the range of frequencies used by cellular phone systems. Urge them to report back to the class with the frequencies and compare them with the frequencies used for radio and television transmissions. **learning modality: logical/mathematical**

Cellular Phones

Teach Key Concepts (L2)

Cellular Phones and Microwaves

Focus State that cellular phones send and receive radio signals over short distances.

Teach Tell students that the radio waves used for cellular phones are microwaves. Ask: **Where are microwaves in the electromagnetic spectrum?** *(At the upper end of radio waves, just below infrared rays)* **How much energy do microwaves have, compared with other radio waves?** *(More energy, because of their higher frequencies)*

Apply Ask: **If microwaves are high-energy radio waves, why can cellular phone signals travel only short distances?** *(Sample answer: Because cellular phones are small, low-power units)* **learning modality: verbal**

Lab zone Build Inquiry (L2)

Modeling Cellular Phone Transmission

Materials small ball

Time 5 minutes

Focus Tell students they will model how a cellular phone system works.

Teach Organize students into small groups, or "cells." Give the first group the ball, and tell them it represents a message. Then, have groups pass the ball from one to another. Ask: **How is the model like an actual cellular phone system, and how is it different?** *(Sample answer: The message was transmitted from cell to cell, but much more slowly.)*

Apply Ask: **How fast are messages transmitted in a cellular phone system?** *(At the speed of light)* **learning modality: kinesthetic**

Monitor Progress (L2)

Writing Ask students to write a paragraph describing how microwaves are transmitted by a cellular phone system.

Answers

Figure 15 It will not be able to transmit and receive radio waves.

Reading Checkpoint 1,000 hertz

Reading Checkpoint Regular calls, paging, and short text messages and video.

Communications Satellites

Teach Key Concepts L2

Bouncing Radio Waves

Focus Use a familiar sports analogy to introduce communications satellites.

Teach Call on a student to describe how to make a basket in basketball by bouncing the ball off the backboard. Explain that a communications satellite is somewhat like the backboard. Radio waves cannot be sent great distances directly over Earth's surface because the surface is curved. Instead, the waves are bounced off a satellite, which returns them to Earth on the other side of the horizon.

Apply Ask: **Why might more than one satellite be needed for this purpose?** *(Sample answer: One satellite might not be able to bounce the radio waves far enough.)* **learning modality: verbal**

Lab zone Teacher Demo L1

Modeling a Communications Satellite

Materials globe, marble

Time 5 minutes

Focus Use a globe and a marble to model how a communications satellite is positioned to reflect radio waves over Earth's surface.

Teach In the feature, have students find the altitude at which communications satellites orbit Earth. *(About 35,000 km)* Tell students that Earth's diameter is a little less than 13,000 km. Then, ask: **About how far above the globe would a communications satellite be?** *(A little less than three times the globe's diameter.)* Holding the marble at the correct height, point out the area of Earth's surface that the satellite could "see."

Apply Ask: **How would you use communications satellites to transmit radio waves from one side of Earth to the other?** *(Sample answer: By using more than one)* **learning modality: logical/mathematical**

Go Online SCI LINKS NSTA

For: Links on using waves to communicate
Visit: www.SciLinks.org
Web Code: scn-1534

Download a worksheet that will guide students' review of Internet resources on using waves to communicate.

Go Online SCI LINKS NSTA

For: Links on using waves to communicate
Visit: www.SciLinks.org
Web Code: scn-1534

Communications Satellites

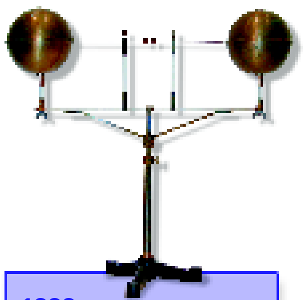
Satellites orbiting Earth are used to send information around the world. Communications satellites work like the receivers and transmitters of a cellular phone system. **Communications satellites receive radio, television, and telephone signals and relay the signals back to receivers on Earth.** Because a satellite can "see" only part of Earth at any given time, more than one satellite is needed for any given purpose.

Satellite Phone Systems Several companies have developed satellite phone systems. The radio waves from one phone are sent up to a communications satellite. The satellite transmits the waves back to the receiving phone on Earth. With this kind of phone, you can call anywhere in the world, but the cost is greater than using a cellular phone.

Science and History

Wireless Communication

Since the late 1800s, many developments in communication have turned our world into a global village.



1888 Electromagnetic Waves
German scientist Heinrich Hertz proved that radio waves exist. Hertz demonstrated that the waves could be reflected, refracted, diffracted, and polarized just like light waves.

1895 First Wireless Transmission
Italian engineer and inventor Guglielmo Marconi successfully used radio waves to send a coded wireless signal a distance of more than 2 km.

1901 First Transatlantic Signals
On December 12, the first transatlantic radio signal was sent from Poldhu Cove, Cornwall, England, to Signal Hill, Newfoundland. The coded radio waves traveled more than 3,000 km through the air.

1923 Ship-to-Ship Communication
For the first time, people on one ship could talk to people on another. The signals were sent as electromagnetic waves, received by an antenna, and converted into sound.

1880 1900 1920

Background

Facts and Figures Before the first working cellular phone network was implemented in Japan in 1979, another wireless phone technology, the mobile telephone, was developed and used in the United States. The first mobile phones were introduced in the U. S. in 1946. To place a call, the caller would scan the dial for an unused channel and call the operator, who would then dial the number. The phones worked like a CB radio or two-way radio set: the caller had to hold down a button to talk, so only one person at a time could talk. In 1964, an improved mobile telephone service was introduced. These phones dialed automatically and allowed callers to talk without pushing a button. However, only a limited number of channels was available. The first cellular phone system in the U. S. was installed in 1983.

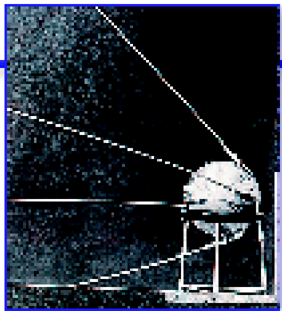
Television Satellites Both television networks and cable companies use communications satellites. First, the television signals are changed into AM and FM waves. These radio waves are sent up to satellites. Then the signals are relayed to local stations around the world.

Some people have their own antennas to receive signals for television programs directly from satellites. Many of the antennas are dish-shaped, so they are known as satellite dishes. Older satellite dishes were very large, more than 2 meters in diameter. But newer dishes are much smaller because the signals from satellites have become more powerful.

Television signals from satellites often are scrambled to make sure that only people who pay for the programs can use the signal. Customers need a decoding box to unscramble the signals.

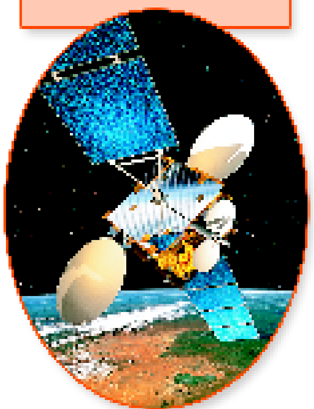
Writing in Science

Research and Write Use library or Internet resources to find out more about Guglielmo Marconi. Imagine that you were hired as his assistant. Write a short letter to a friend that describes your new job.



1957 *Sputnik I*
On October 4, the Soviet Union became the first country to successfully launch an artificial satellite into orbit. This development led to a new era in communications. Since then, more than 5,000 artificial satellites have been placed in orbit.

1963 Geosynchronous Orbit
Communications satellites are launched into orbits at altitudes of about 35,000 km. At this altitude, a satellite orbits Earth at the same rate as Earth rotates.



1979 Cellular Phone Network
In Japan, the world's first cellular phone network allowed people to make wireless phone calls. Today, cellular phone towers like the one above are common.

1960 1980 2000

Science and History

Focus State that the discoveries and inventions in the timeline are important, because wireless communication has turned the world into a global village. Because of wireless communication, you can talk with someone on another continent almost as clearly as you can talk with someone face to face.

Teach Guide students in understanding how important some of the developments in the timeline were to the development of wireless communication. Ask: **How did Heinrich Hertz's discoveries in the 1880s contribute to the later development of wireless communication?** *(Hertz proved that radio waves exist and that they behave like light. This was the basis for all later developments in wireless communication, because wireless communication uses radio waves.)* **Who was the first person to successfully transmit a wireless signal using radio waves, and when did he do it?** (*Guglielmo Marconi in 1895*) **Why was the launching of *Sputnik I* an important event for wireless communication?** *(It was the first artificial satellite that was launched into orbit. This event enabled satellite communication and led to a new era in wireless communication.)*

Writing in Science

Writing Mode Research

Scoring Rubric

4 Exceeds criteria; includes many interesting and relevant details in a creative letter that clearly conveys the job of Marconi's assistant

3 Meets criteria

2 Includes some relevant details in a letter but contains errors

1 Includes only a general description and/or contains serious errors

Background

Integrating Science Meteorologists rely on satellite transmissions to analyze Earth's weather. Certain weather satellites orbit from one pole to the other, rather than around Earth's equator. These satellites take photographs of Earth and then transmit the images as television signals. Receivers in many nations allow meteorologists worldwide to have constant surveillance of weather systems.

The first meteorological satellite was put into orbit in 1960. Since then, the United States has launched several geosynchronous satellites that orbit at the same rate as Earth rotates on its axis. When images from these satellites are used together, they can provide continual global weather coverage. Weather satellites have also been launched by Japan and Russia.

Monitor Progress L2

Writing Have students describe how television networks use communications satellites to send signals to local stations around the world.

Monitor Progress L2

Answers

Reading Checkpoint Global Positioning System

Assess

Reviewing Key Concepts

1. a. Radio waves **b.** A radio station converts sound into electronic signals that are then converted into a pattern of changes in the amplitude of a radio wave. A transmitting antenna broadcasts the radio wave. Your radio receives it and converts it back into sound. **c.** In AM waves, signals are coded as changes in wave amplitude; in FM, signals are coded as changes in wave frequency. AM waves have constant frequency; FM waves have constant amplitude. AM waves reflect off the ionosphere, so they can be received at a greater distance than FM waves, which penetrate the ionosphere. FM waves are received more clearly and produce better sound quality. Both AM and FM waves are radio waves that carry a coded signal from a broadcasting station to a receiver.
2. a. Microwave signals are transmitted by a cellular phone and received by a tower that relays the signals to a hub. **b.** The signal is passed via connecting wires to the hub. The hub sends the signal to another tower, which transmits it. The signal can then be received by another cellular phone user. **c.** The phones might interfere with each other.
3. a. Phone-system satellites, television satellites, and GPS satellites **b.** Communications satellites receive radio, television, and telephone signals and relay the signals back to receivers on Earth. **c.** Your altitude

Reteach L1

Call on students to identify the different uses of radio waves in wireless communication.

Performance Assessment L2

Drawing Have students draw a diagram to show how communications satellites receive and transmit radio waves.

All in One Teaching Resources

- *Section Summary: Wireless Communication*
- *Review and Reinforcement: Wireless Communication*
- *Enrich: Wireless Communication*

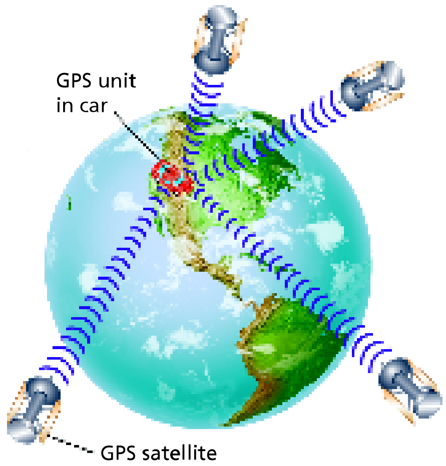


FIGURE 16
Global Positioning System
In the Global Positioning System (GPS), signals from four satellites are used to pinpoint a location on Earth.

Global Positioning System The Global Positioning System (GPS) is a system of navigation originally designed for the military. Now many other people use the system. GPS uses a network of satellites that broadcast radio signals to Earth. These signals carry information that tells you your exact location on Earth's surface, or even in the air. Anybody with a GPS receiver can pick up these signals.

Figure 16 shows how the signals from four GPS satellites are used to determine your position. The signals from three satellites tell you where you are on Earth's surface. The signal from the fourth satellite tells you how far above Earth's surface you are.

Today, GPS receivers are found in airplanes, boats, and cars. In a car, you can type your destination into a computer. The computer uses GPS data to map out your route. A computerized voice might even tell you when to turn right or left.

Reading Checkpoint **What does GPS stand for?**

Section 4 Assessment

Target Reading Skill Using Prior Knowledge
Review your graphic organizer and revise it based on what you just learned in this section.

Reviewing Key Concepts

1. a. Identifying What type of wave carries signals for radio and television programs?
   b. Sequencing Describe the events that bring an AM broadcast into your home.
   c. Comparing and Contrasting How are AM waves different from FM waves? How are they the same?
2. a. Summarizing How does a cellular telephone work?
   b. Interpreting Diagrams A cellular phone transmits a signal to a receiving tower in Figure 15. How is the signal passed on to another cellular phone user?
   c. Relating Cause and Effect Your cellular phone transmits a signal at a specific frequency. What will happen if a cellular phone next to you also uses this frequency?
3. a. Listing What are three kinds of communications satellites?
   b. Reviewing How do communications satellites work?
   c. Predicting If your GPS device received signals from only three satellites, what information about your location would you be missing?

Writing in Science

Cause and Effect Paragraph Just before going to sleep one night, you search for an AM station on your radio. To your surprise, you pick up a station coming from a city 1,000 kilometers away. Your older brother tells you it is because of Earth's ionosphere. Write a paragraph explaining your brother's statement. Be sure to describe how the ionosphere affects AM radio transmissions.

Lab zone Chapter Project

Keep Students on Track At this point, students can collect their surveys and analyze the data. Allow them to use a computer spreadsheet program for this purpose, if one is available. Review graphing skills with the class, and suggest that students also write one or two paragraphs explaining their findings. This will help them organize their findings and conclusions before presenting them.

Writing in Science

Writing Mode Exposition: cause and effect

Scoring Rubric

4 Exceeds criteria; includes concise, accurate explanation with precise description
3 Meets criteria
2 Includes explanation and description but contains errors
1 Includes only general statements and errors

Lab zone **Skills Lab**

Build a Crystal Radio

Problem

Can you build a device that can collect and convert radio signals?

Skills Focus

observing, drawing conclusions, making models

Materials

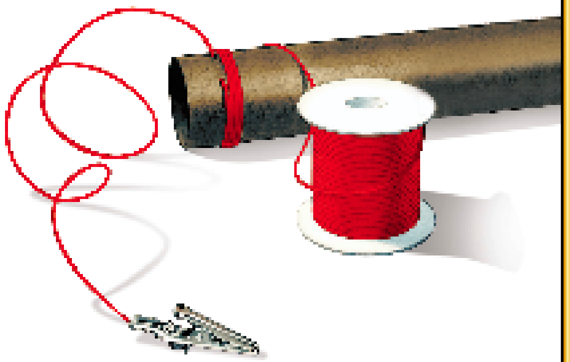
- cardboard tube (paper towel roll)
- 3 pieces of enameled or insulated wire, 1 about 30 m long, and 2 about 30 cm long
- wirestrippers or sandpaper
- 2 alligator clips
- scissors
- aluminum foil
- 2 pieces of cardboard (sizes can range from 12.5 cm × 20 cm to 30 cm × 48 cm)
- masking tape
- crystal diode
- earphone
- 2 pieces of insulated copper antenna wire, 1 about 30 m long, and 1 about 0.5 m long

Procedure

PART 1 Wind the Radio Coil

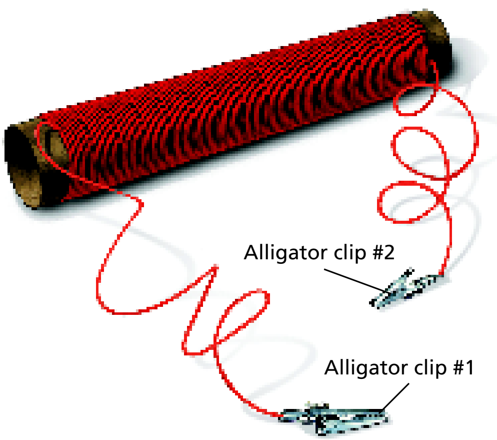
(*Hint*: All ends of the insulated wires need to be stripped to bare metal. If the wire is enameled, you need to sandpaper the ends.)

1. Carefully punch two holes approximately 2.5 cm apart in each end of a cardboard tube. The holes should be just large enough to thread the insulated wire through.
2. Feed one end of the 30-m piece of insulated wire through one set of holes. Leave a 50-cm lead at that end. Attach alligator clip #1 to this lead. See Figure 1.



▲ **Figure 1** Winding the Coil

3. Wind the wire tightly around the cardboard tube. Make sure the coils are close together but do not overlap one another.
4. Wrap the wire until you come to the end of the tube. Feed the end of the wire through the other set of holes, leaving a 50-cm lead as before. Attach alligator clip #2 to this lead. See Figure 2.



▲ **Figure 2** The Finished Coil

Guide Inquiry

Invitation

Ask: **How does a radio work?** *(Sample answer: A radio receives radio waves and converts the waves into sound.)* Explain that radio waves are received by the radio's antenna. Then, the waves are converted into electronic signals. Finally, the electronic signals are converted into sound by the speaker. Remind students how sound waves travel through the air, into the ear, and finally as signals to the brain. Then, ask: **How many different radio stations can you receive with a radio at home?** *(Sample answer: Dozens of radio stations)* **How many radio stations do you predict you will be able to receive with your crystal radio?** *(Sample answer: Few if any stations)*

Lab zone Skills Lab

Build a Crystal Radio L2

Prepare for Inquiry

Key Concept

Students will build crystal radios to receive radio signals and convert the signals into sound.

Skills Objective

After this lab, students will be able to

- observe how many stations their radios can receive and where the stations are located
- draw conclusions about how adjusting the tuning plates affects the reception of radio signals
- make models to determine how they can improve the antennas of their radios

Prep Time 30 minutes
Class Time 60 minutes

Advance Planning

Purchase earphones, crystal diodes, wires, and alligator clips from an electronics supply company. Collect enough cardboard and cardboard tubes for each group, or have students bring them from home. To save time and reduce risk of injury, you may want to strip the ends of the wires yourself. Test the diodes and earphones with an ammeter or multimeter to make sure they work. You may want to set up a demonstration radio ahead of time for students to use as a model as they construct their own radios.

Alternative Materials

You may mount the circuit on a board and use screws instead of clips to make connections.

Safety

Caution students to handle the diodes carefully because they can break easily. Tell students not to connect their radios to electrical outlets or electrical appliances. Students should wear safety goggles when using the wire stripper. Advise them that wire strippers are sharp and to use care when stripping the wire. Review the safety guidelines in Appendix A.

All in One **Teaching Resources**

- Lab Worksheet: *Build a Crystal Radio*

Introduce the Procedure

Have students read through the procedure. Review the steps in the construction process to make sure students understand them. Refer to the apparatus diagrams and explain the purpose of each component. Ask students if they have any questions before they begin. Clear up any questions they may have.

Troubleshooting the Experiment

- Students should test the diode and earphone to make sure they work before connecting them.
- Tell students that the diode arrow must point toward the earphone for the radio to work.
- For Part 4, students can use themselves as the ground by holding the loose end of the shorter antenna wire instead of connecting it to the water pipe or faucet. The longer antenna wire should be extended and lie flat.

Expected Outcome

Students should be able to pick up the signals of some radio stations with the crystal radios they construct.

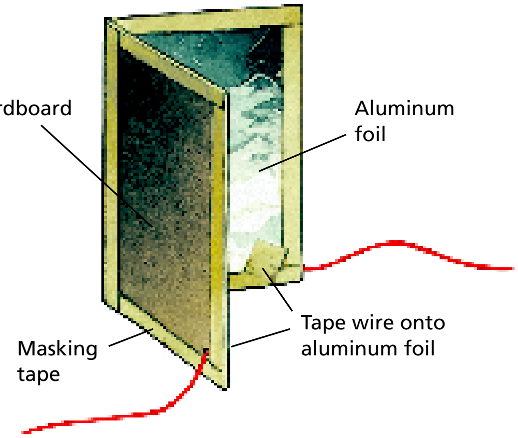
PART 2 Make the Tuning Plates

5. Without wrinkling the aluminum foil, cover one side of each piece of cardboard with the foil. Trim off any excess foil and tape the foil in place.
6. Hold the pieces of cardboard together with the foil facing inward. Tape along one edge to make a hinge. It is important for the foil pieces to be close together but not touching. See Figure 3.

▼ **Figure 3** Taping the Tuning Plates

7. Make a small hole through the cardboard and foil near a corner of one side. Feed one of the short pieces of insulated wire through the hole and tape it onto the foil as shown. Tape the other short piece of insulated wire to the corner of the other side. See Figure 4.

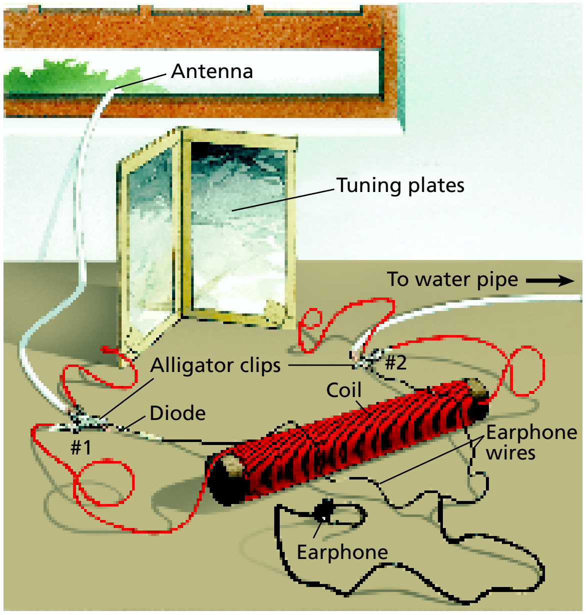
▼ **Figure 4** Connecting the Tuning Plates



8. Connect one end of the wire from the foil to alligator clip #1. Connect the other wire from the foil to alligator clip #2.

PART 3 Prepare the Earphone

9. Handle the diode carefully. Connect one wire from the diode to alligator clip #1. The arrow on the diode should point to the earphone. Tape the other end of the diode wire to one of the earphone wires.
10. Connect the other wire from the earphone to alligator clip #2. See Figure 5.



▲ **Figure 5 The Completed Radio**

PART 4 Hook Up the Antenna

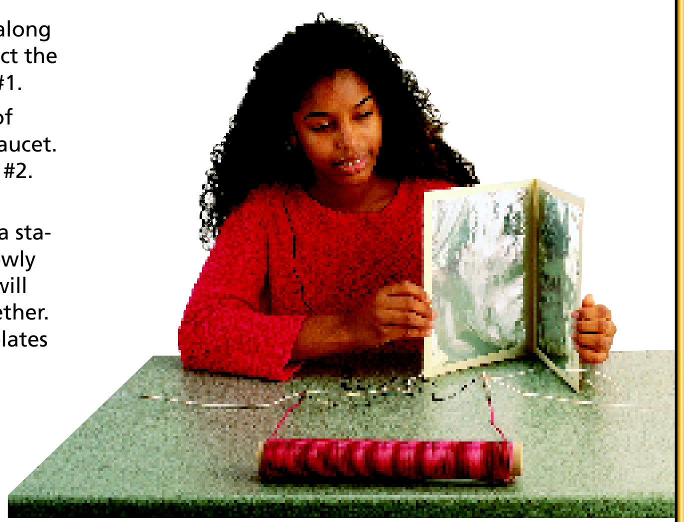
11. String the long piece of antenna wire along the floor to an outside window. Connect the other end of the wire to alligator clip #1.
12. Connect one end of the shorter piece of antenna wire to a cold-water pipe or faucet. Connect the other end to alligator clip #2. See Figure 5.
13. Put on the earphone and try to locate a station by squeezing the tuning plates slowly until you hear a signal. Some stations will come in when the plates are close together. Other stations will come in when the plates are opened far apart.

Analyze and Conclude

1. **Observing** How many stations can you pick up? Where are these stations located, and which station has the strongest signal? Keep a log of the stations your receive.
2. **Forming Operational Definitions** In your own words, give a definition of "signal strength." How did you compare the signal strengths of different radio stations?
3. **Drawing Conclusions** How does adjusting the tuning plates affect reception of the radio signals?
4. **Making Models** You can improve reception by having a good antenna. How can you improve your antenna?
5. **Communicating** Write a paragraph describing the various parts of the radio and how they are linked together.

Design an Experiment

Use a radio to test signal reception at various times of the day. Do you receive more stations at night or in the morning? Does weather affect reception? *Obtain your teacher's permission before carrying out your investigation.*



Analyze and Conclude

1. Answers will vary. Students' logs should describe the position of the tuning plates and the antenna for each station they receive. They should also record observations about the strength of the signal and the amount of static.

2. Students might define signal strength as the amount of energy with which a signal arrives at the radio, which affects how clearly and loudly the station is heard. Students might have compared signal strengths of different stations by rating the amount of static interference on a scale of 1 to 5 or by rating the loudness on a similar scale, with 1 corresponding to the softest station received and 5 to the loudest.

3. Adjusting the tuning plates allows the radio to receive signals of different frequencies from different stations because different stations transmit signals at different frequencies.

4. Students' responses should use examples from their observations to support their opinions. Students might suggest they could improve their antenna and improve reception by using a different type of wire or by changing the length or thickness of the wire.

5. Students' paragraphs should include the main parts of the radio: the radio coil, the tuning plates, the earphone, and the antenna. One end of the coil, one wire from the earphone, and one side of the tuning plates are connected to the antenna. The other wires from the coil, tuning plates, and earphone are connected to the grounding wire that goes to the water pipe.

Extend Inquiry

Design an Experiment Students are likely to receive more stations at night than in the morning. To test whether weather affects reception, students might propose comparing their radio's reception on sunny days with its reception on cloudy days. Give students a chance to test their predictions.